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Endeavor

Chemistry Unit Plan

Due Date: May 1, 2019

Chemistry in the STEM Classroom

Professor Rodriguez

Chemistry Unit Plan

In my high school chemistry classroom, I have developed and am constantly adjusting a year-long project around the theme of space exploration. In different class subjects, students analyze different perspectives on human colonization of a new planet. Throughout the school year in chemistry, students interpret data and participate in explorations that will help them narrow down a selection of planets to land on as see in Figure 1. At the end of the school year, students generate a proposal for which planet they want and use reasoning and evidence from their learning.

As I learn new information about space exploration, I tie in the concepts to the current order of the curriculum and add in small exploration activities. Most of the current project activities revolve around Mars exploration and data, so adding in more general space exploration activities was a goal throughout this semester of learning. In this document, I will identify and expand on five lesson connections to this overarching theme, in the relative order of a chemistry curriculum that goes from microscopic to macroscopic, that were added to this overarching project during the “Chemistry in the STEM Classroom” Endeavor graduate course for testing next school year. Some of the connections are directly from lessons in the course, some are from the topics discussed, and other connections are from exploring more into resources provided. If you need a detailed lesson plan, please let me know.

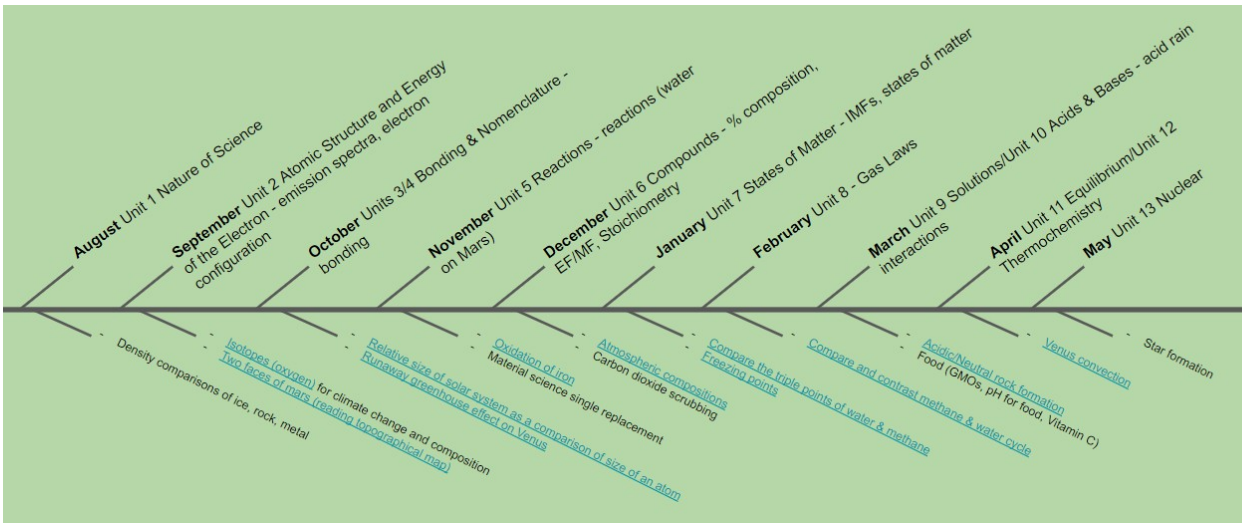

Figure 1. Chemistry units and space connections where the black text on the bottom are the new additions from this course.

Lesson Connection - Density

This lesson connection uses a lesson from the American Chemical Society about using density to identify objects and asks students to then apply to planet data.

Standards and objectives.

During the exploration, students will, “be able to explain that materials have characteristic densities because of the different mass, size, and arrangement of atoms” (ACS). By the end of the exploration, students will be able to use density data provided for the set of fake planets to determine possible composition.

The applicable standards from the Texas Essential Knowledge and Skills (TEKS):

- (2) Scientific processes. The student uses scientific practices to solve investigative questions. The student is expected to: (H) organize, analyze, evaluate, make inferences, and predict trends from data; and (I) communicate valid conclusions supported by the data through methods

such as lab reports, labeled drawings, graphs, journals, summaries, oral reports, and technology-based reports.

- (4) Science concepts. The student knows the characteristics of matter and can analyze the relationships between chemical and physical changes and properties. The student is expected to: (B) identify extensive properties such as mass and volume and intensive properties such as density and melting point;

Pre-assessment and background knowledge.

As this lesson is close to the beginning of the year, students do not need specific skills, other than reading lab equipment. A pre-assessment based on algebra skills involving one variable solutions is suggested. Group students based on math support needed so that you can work with the students in small groups for the calculations.

Lesson description and Endeavor resources.

In the ACS lesson, students use the technique of water displacement to determine the density of several metal rods that have the same mass but different volume. This ACS lesson is an electronic version similar to what I have already done in my classroom. If you have a sufficient class size, I would actually suggest that you have some students complete the lesson where all the rods have the same mass but different volume and some students have rods with the same volume but different masses. When I have students do this, they are then able to collaborate with their peers and defend that both mass and volume have an impact on density. Next, they explore more about the relationship using the PhET density cubes simulation (PhET) and can create their own situations for sinking and floating. After learning about densities in the Endeavor class, I was curious if this concept applied to planets, and found that we can use density information to also predict the compositions of planets. If the planet has a density closer

to 1, it is primarily made of icy components (Figure 2). Those with higher densities will be rocky with possible iron or metallic cores. Those with lower densities will be like our gas giants. Using their knowledge of density, students can first identify what a density of 1, less than 1, and greater than 1 means for planet composition. Then they can compare the densities in our solar system and pose a reason for these observations and, finally, use the densities for the set of project planets to determine compositions.

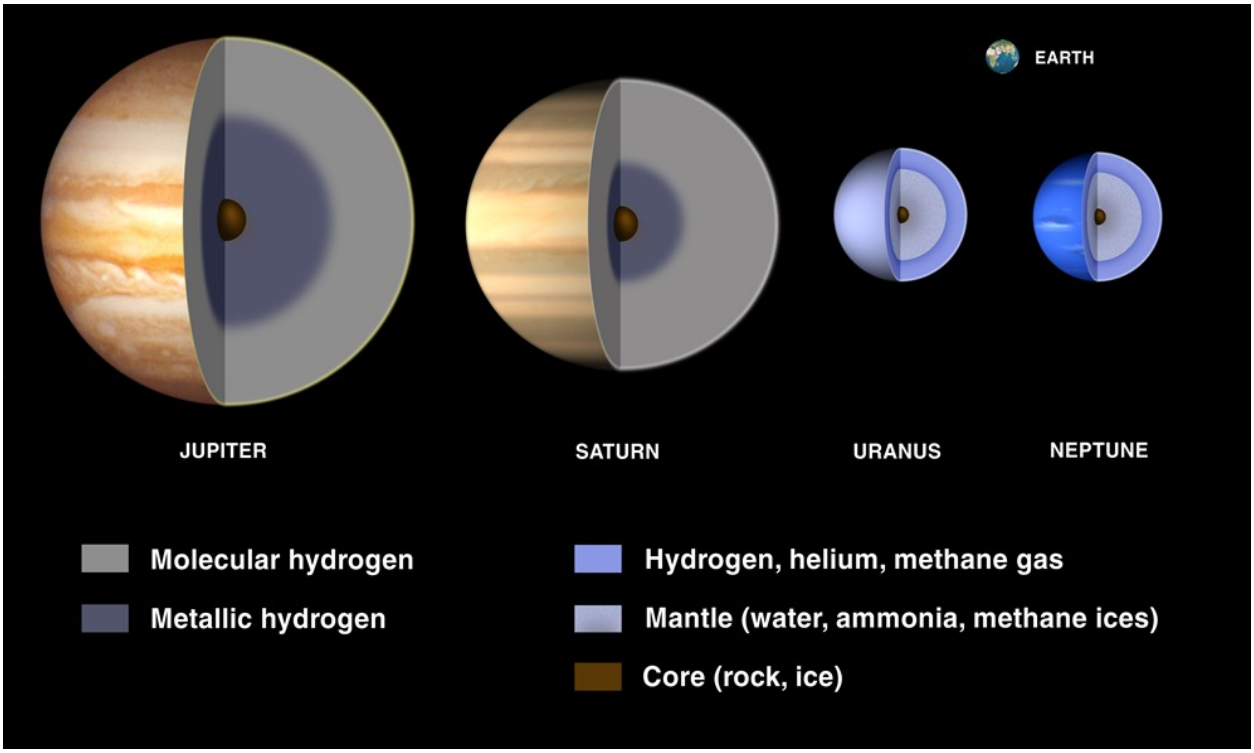

Figure 2. Compositions of planets in our solar system.

Student product and post-assessment.

With regards to the first lab activity, students should generate a data table organizing the data from their group and the groups they collaborated with. They can then submit a proposal identifying each of the rods with justification based on their math and conceptual reasoning.

For the planet connection, students in groups create an infographic, like those from Compound Interest, for how to determine the cores of planets based on density and include the

predictions for the set of planets as rocky, icy, or metallic core. To check their math, they should also include their calculations.

Differentiation opportunities.

To support English Learners (abbreviate as ELs), have your students draw out the different scenarios provided and label the mass and volume similarities and differences.

If you have access to an engineering class, the students can create computer models for each of the rods and then create their own conditions they want to test or have other groups solve their new rod.

To extend the lesson further, students can explore the connection between type of planet core and distance from the central star. Then they can actually somewhat order the set of planets to help in their pursuit of finding a planet to live on, as perhaps being in the habitable zone would be useful and this prediction would be a step towards figuring it out.

Summary.

While this lesson uses minimal authentic data, it does utilize densities of planets in our solar system to build the relationship of density and planet composition. Students are often surprised to realize that, forgetting about lots of confounding variables, Jupiter would float on Earth's oceans! Another strength of this lesson is that while some students move on to the PhET simulation, you can work with the students who need help with the math side of density calculations. Sometimes density at the high school level focuses a lot on the math, so this lesson uses the math as supports by starting with the concept, looking at the math, and then using the results of the math for applications.

Lesson Connection - Isotopes

This lesson connection uses two different applications, climate change and parent planetary bodies, to give purpose to isotopes beyond the traditional application of nuclear chemistry.

Standards and objectives.

By the end of the climate change portion, students will be able to describe the relationship between isotopes and climate change. By the end of the isotopes in planetary bodies' portion, students will be able to determine if the set of planets all came from the same planetary body.

The applicable standards from the TEKS are:

- (3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to: (D) evaluate the impact of research on scientific thought, society, and the environment;
- (6) Science concepts. The student knows and understands the historical development of atomic theory. The student is expected to: (C) calculate average atomic mass of an element using isotopic composition; and

Pre-assessment and background knowledge.

Before doing this lesson, test students on their knowledge of protons, neutrons, and electrons. By the high school level, students will have already had learning on protons and electrons, so a pre-assessment on these topics will let you know if you need to revisit. In addition, have each student sketch the water cycle, describing each portion from the perspective of the water molecules.

Lesson description and Endeavor resources.

Begin the climate change portion by having students time how long it takes them to run a specific distance holding a light bowling ball. Then have them take the same measurement, but while holding a heavier bowling ball. Have a discussion about how it took more energy to get running when they had to run with the extra weight, and how this is similar to the water changing phases in the water cycle, using the States of Matter PhET to help with the idea of needing energy to change phase, if needed. Then you can teach isotopes in your traditional way, activating what they saw about the two bowling balls still being “bowling balls”, just different weights. I have found success teaching isotopes with students using the atom building boards and the Atoms PhET to change subatomic particles. Now extend their learning by having students use the climate data from NASA for global temperature and ice sheets and Riebeek’s website page on oxygen isotopes and climate factors to generate a story about how global temperature affects the movement of water from ice to water vapor and back throughout the seasons.

The isotopes in planetary bodies’ portion is another application of the isotopes they learned about in the previous activity. At the high school level, students also need to prepare for the ACT, so have them create a description for the image in Figure 3, which is from Silberg’s website page. Next, show them a picture of the Shergottite meteorite found in Figure 4 where the gas trapped inside of the meteorite directly matched the atmosphere of Mars, telling us that anything with the same oxygen isotopes came from the same planetary body.

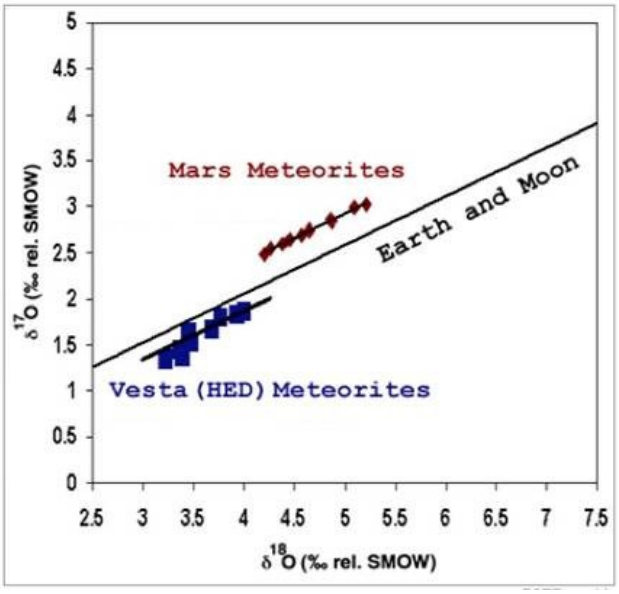

Figure 3. Comparison of oxygen isotopic ratios on Mars, Earth, and meteorites thought to come from Vesta.

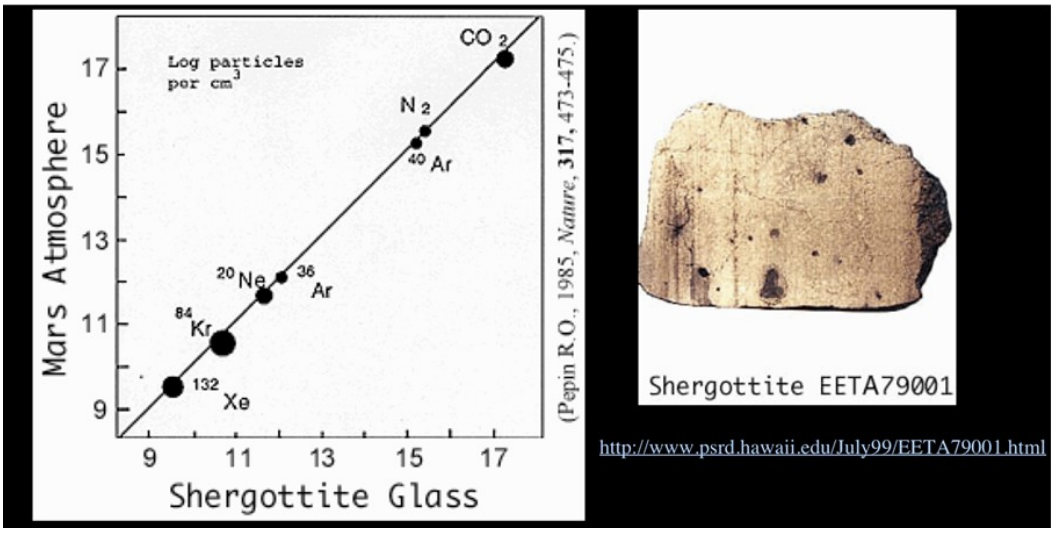

Figure 4. Isotopic data for Shergottite glass compared to Mars.

Student product and post-assessment.

Students will take their water cycle sketch from the pre-assessment and adjust from their new learning of isotopes and heavier/lighter water moving around the globe. They can show this by creating a stop motion animation showing the water molecule movement for one of the earlier

years with data from the NASA site and then create a stop motion for a later year. They will create a side-by-side video to compare and contrast the two animations. You are especially looking for them to show the effect that the warming planet has on the movement of heavier water into the sampling.

Using the isotope data given for the planets in the year-long project, students create a family tree showing how each of the planets are from the same planetary body or different planetary bodies.

Differentiation opportunities.

Students have difficulty connecting the isotope notation to the actual subatomic particles, so I suggest that each time you have them write out the isotope notation, they draw a mini model of the atom or generate the model using the Atom PhET on their computers.

If you have the ability, this would be a good place to have a scientist who has worked with ice core sampling to video call into your class, or record a video for you to play in class. Students can see the physical data sampling techniques for seeing the movement of the water they will describe or have described in the product piece.

Summary.

By having students learn about isotopes in relation to the water cycle is something that I had not considered. Traditionally, we have done nuclear chemistry when we talked about isotopes, but it seemed too technical and fast for students. I think that by using the oxygen isotopes students will have a stronger foundation than when we just have them use the PhET to build atoms. They have an application for their understanding! This also allows us to tie in climate change and its affects earlier in the school year. Then we can just add on to the big ideas as we learn more, for example, ocean acidification in the second semester.

Lesson Connection – Single Replacement Reactions

This lesson connection gives purpose for students generating and then applying the activity series of metals.

Standards and objectives.

By the end of this lesson, students should be able to describe the activity series and predict effective uses of the metals on the activity series.

The Texas standards that were covered are as follows:

- (2) Scientific processes. The student uses scientific practices to solve investigative questions. The student is expected to: (H) organize, analyze, evaluate, make inferences, and predict trends from data;
- (3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to: (A) analyze, evaluate, and critique scientific explanations by using (--) experimental and observational testing, so as to encourage critical thinking by the student;
- (8) Science concepts. The student can quantify the changes that occur during chemical reactions. The student is expected to: (F) differentiate among (--) single replacement (--) reactions;

Pre-assessment and background knowledge.

To engage students and assess prior knowledge, have them brainstorm what engineers and material scientists need to consider about materials to use for building a rover to collect data from another planet. Then have them get in groups and choose from their lists what

considerations relate to the chemistry side of rover building. This is to have students come up with the idea that it is important to consider if the materials used will react with the environment,

Lesson description and Endeavor resources.

In the Spacecraft Materials lesson from NASA's JPL Educator Resources, students act like NASA material scientists by developing an understanding of the properties of metals under conditions very unlike those on Earth and apply this knowledge to determine which material should be used to construct a rover going to a planet like Venus. Rather than a traditional lesson where students are told about the activity series of metals and do practice problems, this lesson focuses on inquiry based instruction and students coming up with situations in which knowing the information would be useful. First, students look at the physical properties of five different metals and note similarities and differences, as seen in Figure 1. Then, students react with copper sulfate solution and note observations at 0 minutes, 5 minutes, and 10 minutes, taking pictures at each of the time intervals for reference. At the end, students rank the metals by reactivity. Now have students select a planet, look up the conditions, and then determine metals that would be non-reactive for that planet. As this is still in first semester of chemistry, students will not have chosen a planet from the project list, but they can suggest a metal or two to use for each of the planets on the list based on potential reactivity from the activity series.

Student product and post-assessment.

Students will have a self-generated activity series that can be checked with the accepted activity series. Students can also be given a single replacement reaction and asked to determine if the reaction will occur, or not. The uniqueness of the student product comes into play when they propose materials to be used for building a rover to their selected planet and the planets for the project.

Differentiation opportunities.

For your advanced students, add in the challenge of cost analysis for certain materials that would add an engineering element to the chemistry focused lesson.

To increase collaboration, I suggest adding in more metals to the list for testing, but have each group test different metals, with some similarities. Then you can create a class ranking of the metal activity series. If you are able to use sodium as one of your metals, safety protocol followed, then they can make predictions about the rest of the alkali metals to fill out their list.

Summary.

The lesson focused on students collecting, synthesizing, interpreting, and applying data to new situations directly related to current space exploration. This enhances traditional exploratory lessons by giving purpose to testing the reactivity of metals and introducing the need for scientists and engineers to selectively choose materials based on environmental conditions.

Lesson Connection - Stoichiometry

Now that we have reached the point in the year where students have decided what the planet potentially looks like and how to construct a rover that will not disintegrate upon arrival, students can begin to explore the human component of space exploration. This lesson builds an analogy to chemical filtration by having students construct a physical filtration representation for carbon dioxide scrubbing.

Standards and objectives.

By the end of this lesson, students should be able to perform stoichiometric calculations involving carbon dioxide scrubbing for space exploration.

The Texas standards that were covered are as follows:

- (2) Scientific processes. The student uses scientific practices to solve investigative questions. The student is expected to: (E) plan and implement investigative procedures, including asking questions, formulating testable hypotheses, and selecting equipment and technology
- (8) Science concepts. The student can quantify the changes that occur during chemical reactions. The student is expected to: (G) perform stoichiometric calculations, including determination of mass and gas volume relationships between reactants and products and percent yield; and

Pre-assessment and background knowledge.

I would suggest that students already know the basics of unit conversions and also stoichiometry, using the proportion method or dimensional analysis method. They do not need any background information on carbon dioxide scrubbing. As an engagement piece, consider having students make predictions for the answers to the post-lab questions in the lesson presented.

Lesson description and Endeavor resources.

NASA's JPL Educator Resources lesson called "The Air Up There" has students,

- Design an air-recycling system capable of capturing simulated carbon dioxide so astronauts can breathe safely while on the International Space Station or a future Mars mission.
- Build and test a filter capable of "scrubbing" carbon dioxide out of the atmosphere while allowing air to flow.
- Calculate the efficacy of the filter.
- Use stoichiometry to determine how many filters are needed for a prolonged, human space mission (NASA JPL).

Once they complete this lesson, there is an extension to the specific chemical filter being tested for Mars, called the Mars Oxygen ISRU Experiment (MOxIE).

Student product and post-assessment.

Students will now compare their predictions to the calculated answers from the lesson and create a budget spreadsheet with formulas that they generate to detail the number of Contaminant Control Cartridges needed and the days to run MOxIE. This spreadsheet should be useful for project scientists to plug in number of astronauts and the spreadsheet will generate output to let them know how much supplies they will need. To relate to the overarching year-long project, students can now perform calculations based on the distances to the set of planets. Perhaps some now are not feasible due to supplies required to support human life on the journey. They should now have a narrowed down list of planets by the end of the semester to narrow down more second semester.

Differentiation opportunities.

The JPL lesson already provides an extension activity focused on the health of the pilots with regards to potential calcium deficiency. Advanced students should include these calculations in their spreadsheet.

To increase the challenge, consider giving students constraints on the size of the filter or require that it allow for a certain percentage of the particles to go through the filter to represent the current limitations that we have.

For students who are still learning stoichiometry, create dominoes that have all of the conversion factors needed for the problems, with the conversion factor flipped on the other side of the domino. Then students simply will need to line up the dominoes to match the situations given in the lesson.

Summary.

Life and death situations are always positive for student engagement and this lesson provides a direct reason for students to get their calculations correct. If not enough supplies are brought on board, the astronauts would begin breathing higher levels of carbon dioxide.

Lesson Connection - Food

The final big connection that I learned about during this course related to the food requirements of space exploration, between what to bring and what to potentially grow in new planet environments. Students will explore genetically modified organisms, the effect of pH on growing, the energy in food, and methods to test vitamin C in foods.

Standards and objectives.

By the end of these mini explorations, students will be able to describe genetically modified organisms, the effect of pH on growing food, and recommend foods high in vitamin C based on their own testing.

The Texas standards that were covered are as follows:

- (3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to: (B) communicate and apply scientific information extracted from various sources such as current events, published journal articles, and marketing materials;
- (10) Science concepts. The student understands and can apply the factors that influence the behavior of solutions. The student is expected to: (G) predict products in acid-base reactions that form water; and (H) define pH and calculate the pH of a solution using the hydrogen ion concentration.

Pre-assessment and background knowledge.

Occurring at the beginning of an acids and bases unit, students would benefit from already knowing about molarity and solutions. A suggested warm up question is to ask students how food is made. Some students may already know that some foods are genetically modified or that different environmental conditions affect food growth.

Lesson description and Endeavor resources.

The first mini exploration is related to genetically modified organisms. Students can use the ProProfs quiz to see where they are starting with their GMO knowledge. Group students based off of this quiz, either in homogeneous or heterogeneous groups depending on the level of your students. They can then explore the Laporte website to learn about at least three different perspectives of GMOs. Based on this, they will group with students of similar mind to create an outline of important information. Once both sides have an outline, or more than two if your students create more than two perspectives to GMOs, have a small debate where students can hear issues and provide rationale.

The second mini exploration is related to the effects of pH on food sustenance. Students will complete IFT Experiments in Food Science Series' lab that explores the effect of heat and pH on green vegetables. Students create an e-mail report to send to their chosen frozen vegetable company describing ideal conditions for their product. I would suggest that this be done as the beginning of the acids and bases unit as it introduces the concept of pH.

The third mini exploration for food considerations of space travel is using titrations to determine vitamin C content in food. Each group can come up with one or two food items that they want to test, that will still work with the limitations of color, and the share the results in an open forum. Students are often surprised by the results. As a final product, students would create an Instagram, Facebook, or Twitter post with suggestions for readers about where to get the most

vitamin C. I suggest that this occur towards the end of an acids and bases unit as a review of the unit.

The fourth and final mini exploration is related to the amount of energy that is stored in food, available to consumers in varying amounts. Students will complete a basic calorimetry experiment from Prey-Leudtke by burning different samples of food. I have my own lesson doing this, but this specific lesson was suggested in the resources for Endeavor. Students will generate a “buy this, not that” poster to be posted in local gyms for foods where consumers should get their most efficient energy, not taking into account biological factors. I would suggest that this occur during the thermochemistry unit for energy transfer.

Student product and post-assessment.

Student products were mentioned in the lesson description above. With regards to the year-long project, students will create a print and television ad or social media campaign for their specific planet, since at this point in the year they will have narrowed down their planet. Their campaign should focus on the food side of taking care of the humans who select to explore this planet with them. Effect campaigns or advertisements would include answers to: will they be using GMOs, what foods will be offered to make sure that consumers get the necessary amount of energy, how can consumers trust that they know what is in their food options, and how can they account for environmental conditions affecting food growth.

Differentiation opportunities.

If you have not trained your students for full-blown debates, consider having each side of the debate post their outline online and then letting the other side leave feedback in the form of comments on their electronic document. Then the groups can respond to the comments with a summary paragraph acknowledging the other side.

The three labs suggested can be shortened depending on the time remaining in the year, but they easily cover what are traditionally taught topics.

Summary.

The connections offered in the food section are directly related to the immediate surroundings of students and apply to the needs for human space exploration. In addition, each of the connections offered allows for students to see big picture ideas beyond the math.

Conclusion

We have seen the application of STEM ideas and, more specifically, space exploration guided by NASA data in the form of density, isotopes, single replacement reactions, stoichiometry, growth of food, and energy in food. These lessons provide real world context to chemistry standards that are required, but also require for students to collaborate, create, critically think, and communicate, the “Four C’s” of 21-st century skills, with are just general learning skills at this point!

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